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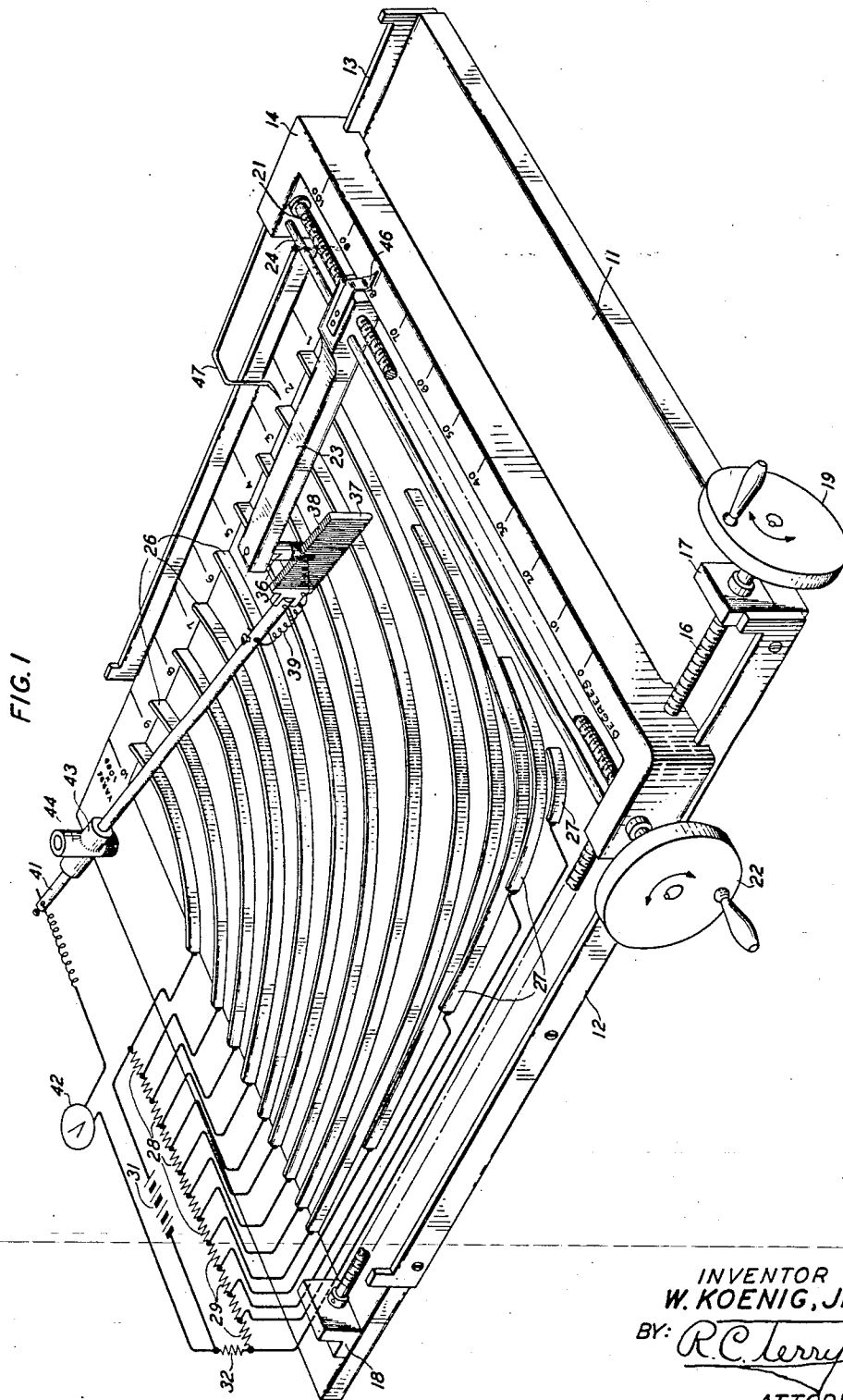
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2,452,664

INTERPOLATING POTENTIAL DIVIDER AND COMPUTER

Filed Oct. 20, 1943

4 Sheets-Sheet 1



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4 Sheets-Sheet 2

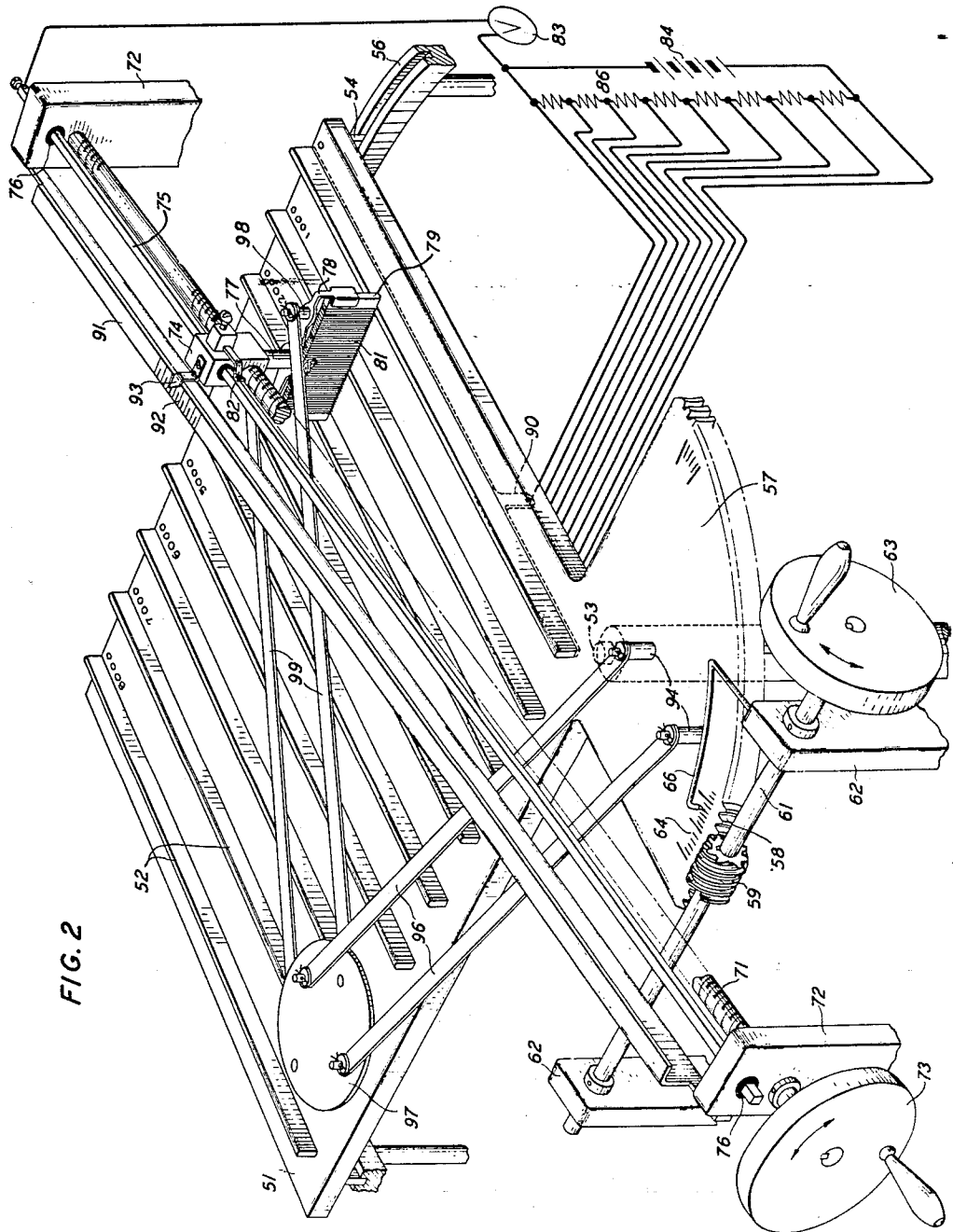


FIG. 2

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4 Sheets-Sheet 3

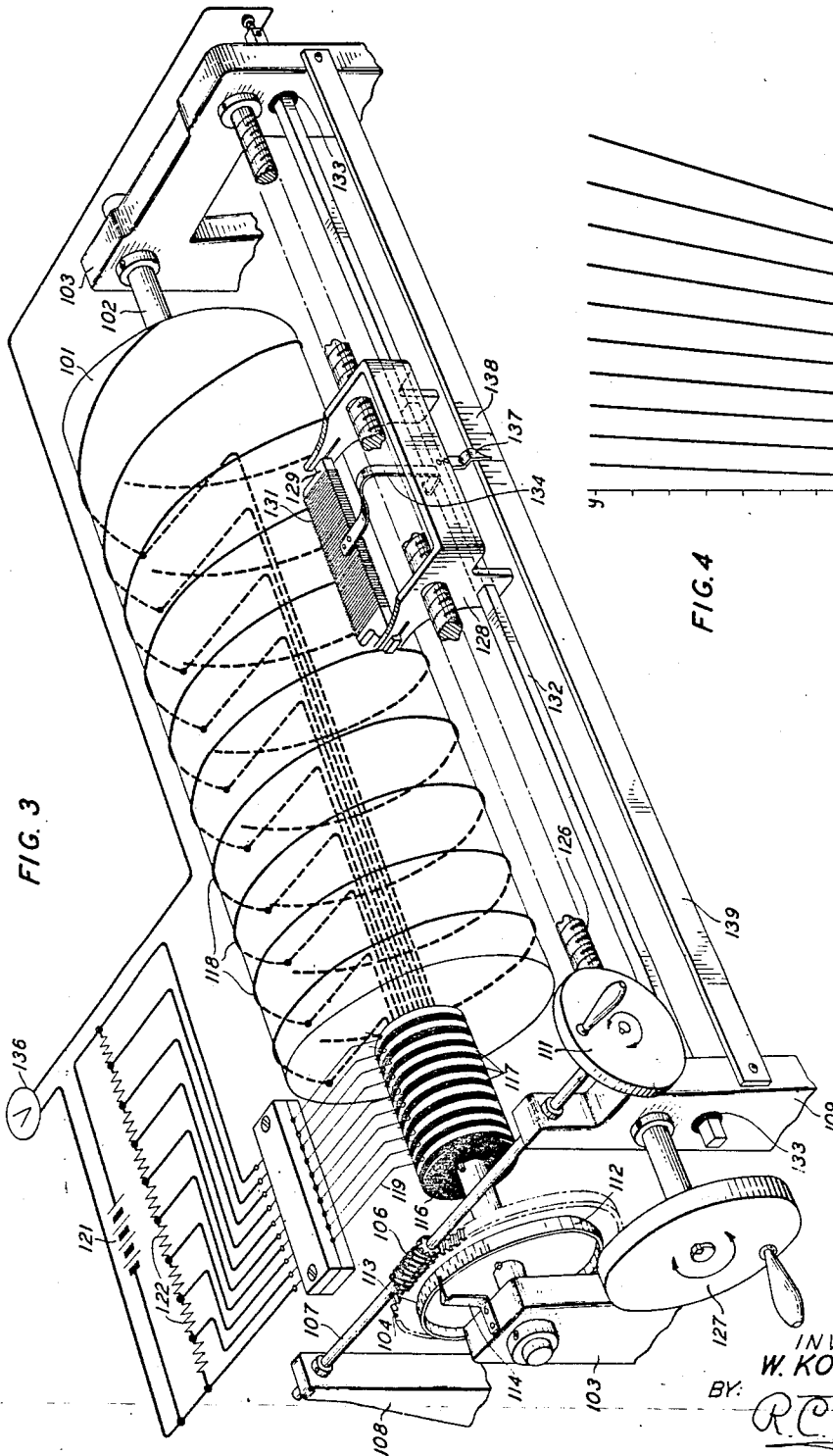


FIG. 3

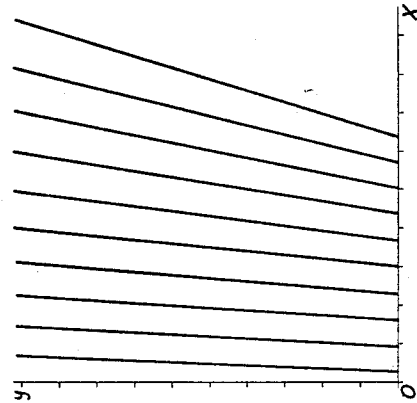


FIG. 4

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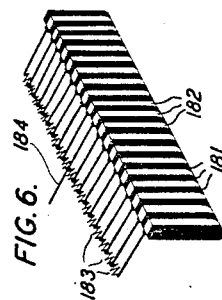
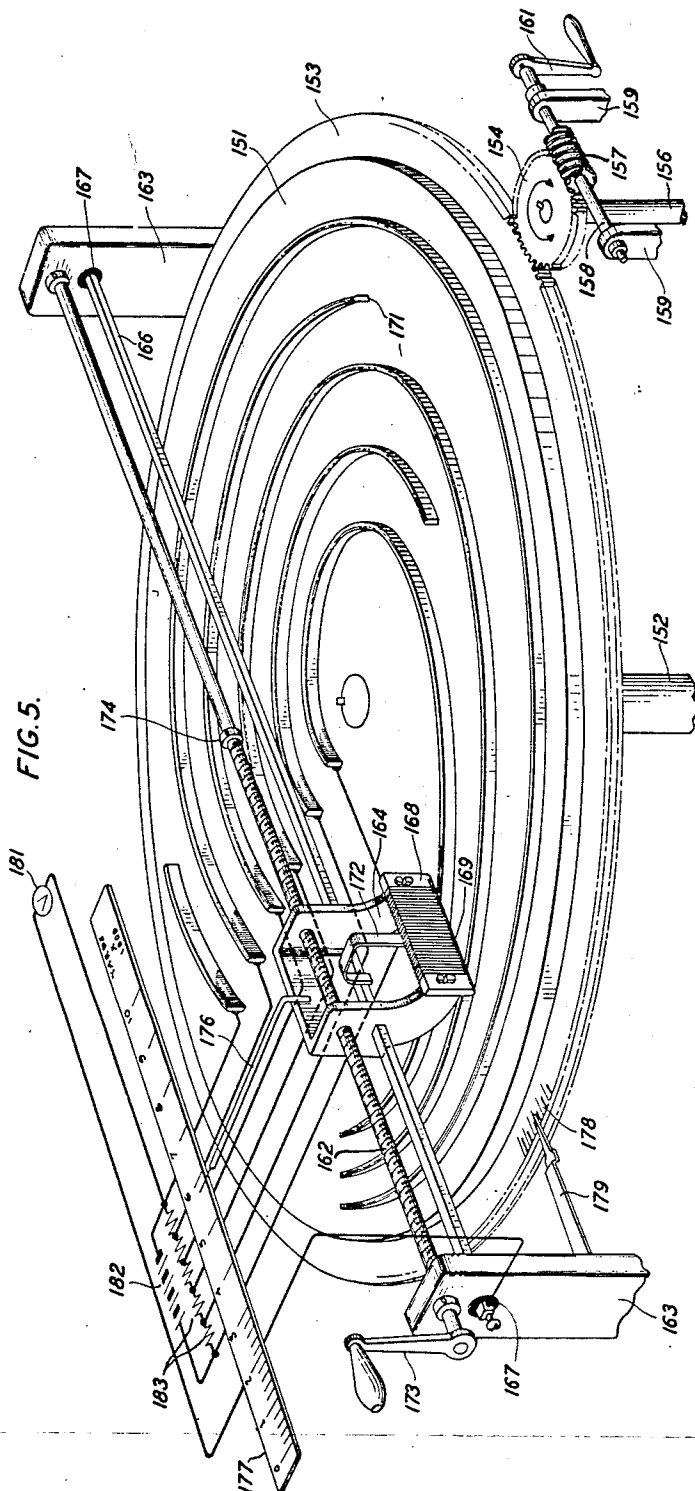
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INTERPOLATING POTENTIAL DIVIDER AND COMPUTER

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4 Sheets-Sheet 4



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24 Claims. (Cl. 235—61.5)

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This invention relates to potential dividers and particularly to the application of potential dividers to the solution of algebraic, geometric and trigonometric functions.

An object of the invention is to provide a simple double-entry potential divider.

Another object of the invention is to provide a potential divider having a plurality of spaced conductive elements and a contacting instrumentality arranged to interpolate potential values between adjacent ones of the conductive elements.

Another object of the invention is to provide simple, easily constructed and easily operated devices for solving mathematical functions.

Another object of the invention is to provide voltage dividers of different types adopted in form and mode of operation to solve particular mathematical functions.

The invention features a voltage divider having a contactor and a plurality of narrow elongated conductive elements, and means for producing relative movement between said contactor and said conductive elements in two directions so that the contactor may be moved into engagement with any part of any of said conductive elements.

The invention further features a voltage divider having a contactor and a plurality of spaced narrow elongated conductive elements in which the contactor is in the nature of a card of sufficient length to span a minimum of two of the elongated conductive elements, carrying a closely spaced winding of fine insulated conductive wire having the insulation removed along one edge of the card for engagement of the wire with the elongated conductive elements, the winding on the card having a potential dividing tap terminal, preferably a center tap for connection in an electrical circuit including the conductive elements, the winding of the contactor, a source of power and an electrical potential indicator for interpolating the position of the center-tap of said winding relative to the adjacent conductive elements on either side of said center-tap as relative movement between the contactor and the conductive elements occurs.

The invention also features means for keeping the contactor card substantially normal to the conductive elements at any point of contact.

In accordance with one embodiment of the invention, a flat plate has secured to opposite sides

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thereof a pair of rails upon which a carriage is movable by means of a lead screw which may be rotated by any convenient means. The carriage has a manually rotatable lead screw extending at right angles to the first-mentioned lead screw and threadedly engaging an arm which travels along the carriage as the lead screw is rotated. The arm pivotally supports a depending contactor card mounted edgewise and having a closely spaced winding of fine insulated wire. Beneath the contactor card the mounting plate carries a plurality of thin conductive strips set on edge in the mounting plate, which is preferably of insulating material. The conductive strips are bent into configurations representing a family of curves, each strip representing a constant function of two variables. The contactor card is preferably of such length that it will just engage three contact strips when it is positioned where the distance between adjacent contact strips is greatest. Thus the contactor card will never fail to engage a minimum of two contact strips as it is moved under the joint control of the two lead screws, each of which adjusts the position of the contactor card in accordance with one of the two variables. The contactor card has secured thereto a guide rod which is slidable in a member pivoted near one corner of the mounting plate. The pivoted member is mounted in a position of mean approximation of equidistance from all portions of each curve so that the plane of the contactor card as it engages any contact strip shall as nearly as possible be normal to the plane of a tangent to the contact strip at the point of engagement.

The successive contact strips are interconnected by resistors the values of which are proportional to the constant values of the functions which the contact strips represent, and a source of electrical potential is connected across this series of resistors. An electrical potential measuring instrument is connected to one terminal of the source of current and is also connected to the potential dividing tap terminal of the conductive winding on the card.

As the card is adjusted by means of the two lead screws to a position representing a chosen value of each of the two variables of the function, a voltage is impressed by two or more of the contact strips across a portion of the winding of the

contactor card. The voltage across the two contact strips between which the tap terminal of the contactor card is disposed will be divided at the tap and the potential measuring instrument will indicate the total voltage from one terminal of the source of potential to the tap terminal of the contactor winding. It will thus give an indication of the exact position of the tap terminal of the contactor winding relative to the two contact strips adjacent to it and will interpolate between the values of the functions represented by the two contact strips. In this way, a relatively small number of contact strips well spaced may be employed, thus simplifying the construction of the device and at the same time a vast number of intermediate values of the function may be read from the measuring instrument.

In accordance with another embodiment of the invention, the supporting plate for the contact strips is mounted to rotate about one of its corners. A worm and pinion mechanism operated by a crank is provided for rotating the mounting plate. The contactor card is pivotally supported by a block which is caused to traverse the mounting plate by means of a lead screw operated by a crank. A parallel motion mechanism interconnects the contactor card and the mounting plate mechanically. The contact strips are straight instead of curved and are parallel to each other. They may represent the same function of the same two variables as in the previously described embodiment because the relative movement between the contact card and the contact strip is a combination of straight line and rotary movement whereas in the previously described embodiment, the movement of the contactor card is the combination of straight line movement in two directions. Since the contact strips are straight and are parallel, the contactor card may be kept normal to the contact strips at all times and in all positions by means of the parallel motion mechanism.

In another embodiment of the invention, the contact strips representing the function of the two variables are in the form of spirals upon the periphery of a drum, each separate one of the spirals just failing to overlap so that the contactor card which is movable along the drum parallel to the axis thereof by means of a lead screw cannot engage any one conductive strip at more than one point. The cylinder is rotatable in accordance with one of the variables entering into the function and the contactor card is movable longitudinally of the cylinder in accordance with the other variable factor.

Still another embodiment of the invention employs a rotatable disc as the mounting for the contact strips, the strips being curved into the configuration of a family of spirals in accordance with several values of the function. A rotatable lead screw extends across the rotatable disc above it and supports the contactor card radially of the disc. Rotation of the mounting disc for the contact strips represents one variable factor entering into the function and movement of the contactor card by means of the lead screw radially of the rotatable plate represents the other variable factor.

For a complete understanding of the invention, reference may be had to the following detailed description to be interpreted in the light of the accompanying drawings wherein:

Figs. 1, 2, 3 and 5 are perspective views showing four different embodiments of double entry voltage dividers;

Fig. 4 is a development of the spiral contact

strips of the voltage divider shown in Fig. 3; and, Fig. 6 is a schematic perspective view showing a modified form of tapped contactor.

Referring now to the drawings and particularly to Fig. 1, the reference numeral 11 designates a rectangular mounting plate which is preferably of insulating material. Mounting plate 11 has secured to two opposite edges thereof the rails 12 and 13. Rails 12 and 13 support a carriage 14 which is movable therealong by threaded engagement with a lead screw 16 journaled in bearing blocks 17 and 18 secured to mounting plate 11. A crank wheel 19 secured to lead screw shaft 16 is manually operable to impart movement to carriage 14 to and fro along rails 12 and 13.

Carriage 14 has journaled in the ends thereof a lead screw 21 which has a crank wheel 22 secured thereto. An arm 23 threadedly engages lead screw 21 and slidably engages a rod 24 carried by carriage 14 parallel to lead screw 21, and the screw 21 and rod 24 support arm 23 in a plane parallel to the surface of mounting plate 11.

Mounting plate 11 has secured thereto a plurality of thin electrically conductive metal strips 26 which may be set in grooves in the surface of mounting plate 11 or may be mounted on the surface and have extending through the plate 11 to the underside thereof, threaded studs or deformable pins to receive threaded securing nuts or to be deformed in the manner of rivets for rigidly securing the conductive strips 26 to mounting plate 11. Strips 26 preferably have their upper edges rounded to provide line contact with a contactor winding which will be described hereinafter.

The conductive strips 26 have configurations representing a family of curves. Specifically, the curves of the contact strips are intended to represent the mathematical relationship $k=y \sin x$. This relationship finds practical utility in calculations involving the range, height and angle of elevation of an object from a given point of observation. Specifically each curve represents a constant value of height of the object, which corresponds to the quantity k in the above equation, the variable quantity y represents range, the ascending values of which are shown along the right-hand edge of mounting plate 11 and the quantity x represents the angle of elevation, ascending values of which are indicated on the carriage 14 from left to right. Values of y (range) from 1 to 10 are indicated on the scale at the right-hand side of mounting plate 11 and these values may also be understood as representing the values of k (height) since the scale of angles of elevation extends only 10 degrees beyond 90 degrees and at the angle of 90 degrees the value of the sine is 1 and $y=k$. All of the curves approach the position of $x=0$ asymptotically since the sine of 0 angle is 0. In the previously recited equation $k=y \sin x$, the value of y goes to infinity for any finite value of k as x goes to 0.

Because of the fact that the curve of $k=1$ rises sharply for values of x less than 20 degrees, there is space in the lower left-hand corner for additional conductive strips. This space represents values of k less than 1 and it is preferable not to bring such additional strips out to the position where $x=90$ or 100 degrees nor to the position where $y=10$ because they would be crowded closely together at that point. Accordingly, several short strips identified by the reference numeral 27 have been shown in Fig. 1. They merely afford values of k for low values of x and y . The units in which the values of k and y are expressed will

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be dependent upon the magnitude of distances involved and may be 1000 feet for example, or 1000 yards or 1 mile as additional examples.

Each conductive strip 26 and 27 is connected to the next adjacent strip by a resistor, those interconnecting the full strips 26 being designated by the reference numerals 28 and those interconnecting the short strips and the resistor interconnecting the full strip 26 nearest to the lower left-hand corner and the adjacent short strip by the reference numeral 29. Since the values of k represented by the strips 26 progress uniformly the resistors 28 are of equal value. The resistors 29 are proportioned to the fractional values of k , the conductive strips of which they interconnect. A battery or other source of potential 31 has one terminal connected to the end of the last resistor 28 and has its other terminal connected to the first of the resistors 29 through a resistor 32. The value of resistor 32 plus the total of the resistive values of resistors 29 is equal to any one of the resistors 28 since the first resistor 28 which is the one connected to the last resistor 29 represents values of k from 1 to 2 and therefore the total of resistor 29 and 32 must represent values of k from 0 to 1.

The arm 23 which is movable along carriage 14 pivotally supports a depending pin 36 which supports a contactor card 37 mounted edgewise. Card 37 may be of any relatively stiff non-conductive material such as fiber or phenolic condensation material and has wound thereon a closely spaced winding of fine insulated conductive wire 38. By virtue of the rounded surface contour of the conductive strips, the number of turns of the conductive winding which a contact strip engages is kept to a minimum. The length of the winding should be such that at the point of greatest distance between adjacent conductive strips 26, the winding of conductive wire 38 engages a minimum of two and a maximum of three conductive strips. The conductive winding has the insulation removed from the face thereof presented in engagement with conductive strips 26 or 27, the insulation on the side of the turns being left undisturbed so that the turns are insulated from each other. The ends of the winding on card 38 are anchored but have no electrical connection. A potential dividing tap lead 39 is brought out from that turn of the winding which is on the axis of pin 36 and the center tap lead 39 is connected to a conductive rod 41 which is rigidly secured to card 37. Rod 41 is connected electrically to one terminal of a voltage measuring instrument 42, the other terminal of which is connected to the junction of battery 31 and resistor 32.

Rod 41 is slidably supported in a bushing 43 which extends through a spindle 44 at right angles to the axis thereof. Spindle 44 is rotatably mounted on mounting plate 11. The purpose of spindle 44, sleeve 43 and rod 41 is to turn card 37 with respect to arm 23 as the card is moved over contact strips 26 and 27 by lead screws 16 and 21 so as to keep card 37 as nearly normal as possible to the contact strips which it engages at the points of contact. Since the configuration of each of the contact strips 26 and 27 is a hyperbolic curve there is no real point of mounting for a spindle 44 which will cause card 37 to intersect any curve of the family normal to a tangent at any point of intersection of the card with the curved contact strip. Accordingly, the location of the axis of spindle 44 on mounting plate 11 is an approximation which will give a minimum average deviation

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from right-angled intersection of the card 37 with the strips 26 and 27 throughout the length of all of the contact strips on mounting plate 11. No great disadvantage results from the fact that the card 37 contacts any two adjacent ones of the contact strips at an angle slightly oblique from a right angle, because the number of turns of the winding 38 from the tap to the two contact strips adjacent to the center tap increases in proportion as the angle of the card deviates from a relation of normality to the two contact strips, provided that the deviation is kept small. This proportionality may be demonstrated by constructing curves representing two adjacent curves of the family, drawing a straight line from one to the other having minimum deviation from a right angle with respect to both curves, selecting any point on the line as the assumed tap point of winding 38 and drawing another straight line intersecting the first at the selected point at an angle to the first line. The angles between the two straight lines are subtended by parts of the two curves and if the angle between the two lines is small the curvature will be slight and the two lines and the two subtending curves will form substantially similar right-angled triangles. It is a well-known theorem of geometry that corresponding sides of similar triangles are proportional. From this it follows that the potential dividing tap of the winding 38 on card 37 will divide the voltage across the two contact strips between which the tap is disposed in substantially the same ratio for deviation of the card over a moderate range in either direction from the nearest possible approximation of perpendicularity with respect to the two contact strips.

In operation of the device crank wheel 22 is operated to bring pointer 46 carried by arm 23 into registry with the indexing graduation on the scale carried by carriage 14 corresponding to the observed angle of elevation of the object under consideration. Also crank wheel 19 is operated to bring pointer 47 mounted on carriage 14 into registry with the indexing graduation on the scale carried by mounting plate 11 corresponding to the observed range of the object under consideration. By these operations the two variables of the function have been registered in the device and the tap point of winding 38 has been moved in accordance with the principles of rectangular coordinate selection to a predetermined point above mounting plate 11, with the winding engaging a minimum of two of the conductive strips. A voltage will be impressed upon that portion of the winding 38 between the points of contact with the conductive strips equal to the voltage across the resistance 29 or 28 connected between the two conductive strips. The tap of the winding will divide the voltage according to its position relative to the two conductive strips and the potential measuring meter 42 will register the potential across resistor 32 plus the aggregate of potential across the resistors 29 and 28 up to that one of the two conductive strips engaged by the winding 38 which is at a lower potential than the other conductive strip then engaged plus the potential across the portion of the winding 38 from the lower potential strip engaged by it to the tap connection. The voltmeter will thus register a voltage indicative of the exact position of the tap of winding 38 relative to the two contact strips between which it is disposed. The contactor winding 38 has interpolated between the two contact strips and has afforded on the voltmeter a reading representing the value of k (height) for the

particular settings of indicator pointers 46 and 47. Furthermore, voltmeter 42 is direct reading since it registers the total voltage from the center tap of contactor winding 38 down to zero voltage. It may, if desired, have its scale calibrated to read in the units, in which the quantity k is measured, which presumably would be the same unit as those in which the quantity y is expressed.

It will be apparent that in some positions of card 37 the conductive winding 38 will engage more than two conductive strips because the spacing of the strips varies continuously. Such multiple contacting of the strips will have no effect on the operation of the device for the reason that it will merely reduce the resistance between those of the conductive strips that it engages by placing its own resistance in parallel with the resistors 29 or 28. This has the effect of reducing the over-all resistance in the external circuit of the battery 31 thereby increasing the current drawn by the resistors from the battery, and the increased current flowing through the reduced resistance provides a substantially constant relationship of voltage at the center-tap of winding 38 from the standpoint of the two conductive strips between which it is disposed, irrespective of the number of turns of winding 38 between the two conductive strips and irrespective of the fact that other sections of the winding 38 may be engaging other conductive strips 26 or 27, and providing a path for a flow of current through such section between such strips.

Fig. 2 shows another embodiment of the invention for solving problems involving the same mathematical relationship as that solvable with the apparatus shown in Fig. 1, namely, the relationship $k=y \sin x$.

In the embodiment of the invention shown in Fig. 2, the mounting plate 51 for the contact strips 52 is pivoted at the point 53 and may be provided on the underside with an arcuate rail 54 which has the point 53 of pivotal mounting of plate 51 as its center and which rests in a groove in arcuate track 56 which has the same center as rail 54. It will be understood that the supporting means for plate 51 comprising rail 54 and track 56 is shown merely by way of illustration and that any well-known antifricition means such as balls confined to travel in a circular raceway may be employed for supporting mounting plate 51 for pivotal movement about point 53.

Mounting plate 51 has integral therewith or secured thereto a quadrant sector plate 57 the arcuate edge of which is provided with pinion teeth 58. A worm 59 secured to shaft 61 meshes with pinion teeth 58. Shaft 61 is journaled in bearing blocks 62 and is provided with a manually operable crank wheel 63 by the operation of which pivotal movement may be imparted to mounting plate 51 through worm gear 59 cooperating with pinion teeth 58. Quadrant sector plate 57 may be provided with scale 64 of indexing graduations calibrated in degrees of angle from 0 to 90 degrees. An indicator pointer 66 mounted on any convenient stationary object such as one of the bearing blocks 62 cooperates with scale 64 to enable sector plate 57 and mounting plate 51 to be adjusted to any desired angular position.

A lead screw 71 is journaled in bearing blocks 72 so positioned that the axis of pivotal movement of mounting plate 51 is perpendicular to and passes through the axis of lead screw 71. A crank wheel 73 is secured to lead screw 71 for imparting rotation to the screw. A block 74 is thread-

edly mounted on lead screw 71 and is guided by square rod 75 mounted in insulating bushings 76 in bearing block 72. Threaded block 74 carries a depending pin 77 which pivotally supports an inverted U-shaped clip 78 to which is secured card 79 having contactor winding 81 thereon. The center tap of winding 81 is connected to a brush 82 which has sliding electrical contact with guide rod 75. Rod 75 is electrically connected to one terminal of a voltmeter 83, the other terminal of which is connected to one terminal of battery 84. Battery 84 is connected across a series of resistors 86 which are preferably of equal resistance value. The end terminals of the end resistors and the junctions of the resistors in the series are connected to the contact strips 52 carried by mounting plate 51, the connections being made in numerical order with the lowermost potential applied to the lowermost contact strip 52 and the highest potential connected to the uppermost conductive strip.

An indexing scale bar 91 is secured to bearing blocks 72 and extends parallel to lead screw 71. Scale bar 91 has indexing scale graduations 92 marked thereon and an indicator pointer 93 mounted on the top of lead screw block 74 traverses scale 92.

It will be noted that the contact strips 52 are straight lines and are parallel. This affords opportunity for keeping card 79 normal to the contact strips 52 without any compromise or approximation. Accordingly, a parallel motion mechanism has been provided for maintaining normality of the card 79 with respect to contact strips 52. Sector plate 57 has secured thereto upstanding fixed pins 94 having their axes on a line parallel to strips 52.

A pair of equal length links 96 are pivoted on the upper ends of pins 94. At their remote ends the links 96 are pivotally connected on centers the same distance apart as the centers of pins 94 to one face of a connector member 97 which has been shown as a disc but which might also be in the form of a square or a cross. Clip 78 which supports card 79 has secured thereto upwardly extending pins 98 equidistant from pin 77 by which clip 78 for card 79 is supported, and pins 98 have equal length links 99 pivoted thereto. The remote ends of links 99 are pivoted to the other surface of connector member 97 at points spaced apart a distance equal to the spacing of pins 98 and on a line at right angles to the line between the pivot connections of links 96 to connector member 97, the relation being such that the two lines bisect each other. Links 96 always remain parallel to each other and maintain the line of their pivotal engagement with connector member 97 parallel to the line of the centers of pin 94. The center line of the connections of links 99 to connector member 97 is at right angles to the center line of the pivot points of links 96 and links 99 always remain parallel to each other and maintain card 79 parallel to the line between the pivotal connections of links 99 to connector member 97. With this parallel motion mechanism, card 79 is kept normal to contact strips 52 as the card 79 is brought into any position with respect to mounting plate 51 as a result of relative movement between card 79 and mounting plate 51.

Whereas in the previously described embodiment of the invention, the contactor card was movable in either of two directions by two lead screws in accordance with the Cartesian system of coordinate axes, in the present embodiment

of the invention card 79 is movable back and forth along lead screw 71. Mounting plate 51 for conductive strips 52 is movable with respect to card 79 about point 53 as an axis and as mounting plate 51 or contactor card 79 or both are moved card 79 turns upon the axis of pin 77, keeping the card normal to contact strips 52.

As previously stated the embodiment of the invention shown in Fig. 2 is arranged to solve problems involving the same mathematical relationship as Fig. 1, namely, the relationship $k=y \sin x$. However, the system operates in polar coordinates instead of Cartesian coordinates. The lowermost contact strip which is labeled 0 represents 0 angle of elevation and is the prime direction or initial ray. Rotation of mounting plate 51 in clockwise direction increases the angle of the lead screw 71 with respect to the initial ray and therefore represents increasing values of angle of elevation, the angle being identified by the quantity x . The axis of the lead screw 71 represents the radius vector of the polar coordinate system and increasing values of this vector proceed toward the right. The length of the radius vector corresponds to the quantity y in the equation, and represents the range of the object under observation. The several conductive strips represent different constant values of the quantity k (height). When the mathematical relationship $k=y \sin x$ is plotted in polar coordinates, the relationship is found to be represented by a straight line. This is the reason that the contact strips 52 in Fig. 2 have this configuration. By substituting polar coordinate operation for Cartesian coordinate operation, the preparation and mounting of the conductive strips is simplified, because they do not have to be bent or curved to the configuration of a family of mathematical curves, no two of which are alike.

The operation of the apparatus is similar to that of the previous embodiment. Crank 63 is operated to bring the scale 64 of sector plate 57 to the position with respect to indicator pointer 66 corresponding to the observed angle of elevation. Crank 73 is operated to move card 79 along lead screw 71 until the pointer 93 indicates the observed range on scale 92. The center tap of winding 81 interpolates between the two conductive strips between which the center tap is disposed and voltmeter 83 then gives a direct reading of the exact position of the center tap of winding 81 and the height of the object under observation is thus obtained. With straight conductive strips 52 equally spaced and with the parallel motion mechanism maintaining card 79 normal to the conductive strip the winding on card 79 may be exactly proportioned so that it never engages three conductive strips simultaneously and never fails to engage two conductive strips simultaneously. As previously stated it is not seriously objectionable to have the winding 81 engage more than two contact strips simultaneously but since the arrangement of straight conductive strips and a contactor card always maintained at right angles to the strip is particularly adapted to limiting the number of conductive strips simultaneously engaged to two strips, it is preferable that the length of the winding be so limited.

Another embodiment of the invention is shown in Fig. 3. In this embodiment of the invention a cylinder 101 is fixed to shaft 102 which is rotatably mounted in bearing blocks 103. Shaft 102 has secured thereto a worm wheel 104 which

meshes with a worm 106 secured to rotatable shaft 107 journaled in bearing blocks 108 and 109. Shaft 107 has secured thereto a crank wheel 111 by the operation of which rotation may be imparted to shaft 107. Secured to worm wheel 104 or to a disc secured to shaft 102 is a flange 112 which carries an indexing scale 113. An indicator pointer 114 is secured to bearing block 103 adjacent to worm wheel 104 and scale 113 and pointer 114 cooperate to indicate the angular position of cylinder 101 relative to a predetermined zero position.

Shaft 102 has also secured thereto a small cylinder 116 preferably of insulating material which carries on its surface a plurality of spaced conductive collector rings 117. Each of the rings 117 is connected electrically through the interior of cylinder 101 to one of a plurality of contact strips 118 carried on the surface of cylinder 101. The collector rings 117 are slidably engaged in electrically conductive relation by a bank of collector brushes 119. The end brushes of the bank are connected to the terminals of a battery 121 and to the end terminals of an electrical series of resistors 122. The intermediate brushes 119 of the bank are connected to the junctions of successive ones of the resistors 122 connected in electrical series.

A lead screw 126 extending parallel to the axis of shaft 102 is journaled in right-hand bearing block 103 and left-hand bearing block 109 and is provided with a crank wheel 127 by the operation of which rotation may be imparted to the lead screw. Lead screw 126 has threaded engagement with a frame 128 which supports a contactor card 129 having a center tapped conductive winding 131. Frame 128 is guided to hold card 129 in a fixed plane by a square rod 132 which is supported in insulating bushings 133 in bearing blocks 103 and 109. The center tap of winding 131 is electrically connected to a brush 134 which has electrically conductive engagement with square rod 133. Rod 133 is electrically connected to one terminal of a voltmeter 136 the other terminal of which is connected to the low potential terminal of battery 121. Frame 128 is provided with an indicator pointer 137 in registry with the center tap of winding 131 and cooperating with an indexing scale 138 inscribed on the surface of a bar 139.

It will be observed that the conductive strips 118 carried by cylinder 101 are in the form of spirals limited to a single turn and having progressively greater pitch from the left-hand end of the cylinder to the right-hand end. A development of the spirals is shown in Fig. 4 wherein it will be observed that the several functions corresponding to the conductive strips are straight lines plotted on Cartesian axes of coordinates. The equation of these lines may be represented by the general equation of a straight line $Ax+By+C=0$ in which A , B and C have constant values for any one line which differ as between the lines, and x and y are the variables. Since the lines on Fig. 4 representing the functions are straight and therefore each line has a fixed slope, each conductive strip on cylinder 101 has a fixed pitch but among the several conductive strips the pitch varies progressively. The conductive strip representing the function having the greatest slope has the least pitch on cylinder 101 and the conductive strips corresponding to functions having lesser slopes have greater pitch. Distances along the axis of cylinder 101, which is the direction in which contactor card

129 is movable, correspond to distances along the horizontal or x axis of Fig. 4, the values increasing from left to right, and circumferential distances on cylinder 101 correspond to distances along the vertical or y axis of Fig. 4, the values increasing in a clockwise direction around cylinder 101 as viewed from the left-hand end, from which it follows that cylinder 101 is rotated counter-clockwise to register increasing values of the quantity y .

The arrangement shown in Fig. 3 is particularly adapted to mathematical operations involving a family of curves in which the field of operation is limited to the extent that the deviation from parallelism with respect to one axis is relatively small. Under these circumstances the movement of contactor card 129 may be confined to a plane and it is not necessary to provide mechanism for keeping the card normal or substantially normal to the several conductive strips because the maximum deviation of the conductive strip having the greatest pitch from normality with respect to the card is relatively small and is within permissible limits. This embodiment of the invention is not limited to conductive strips representing straight line mathematical values, and Fig. 4 merely illustrates a typical set of curves. The spiral strips may be arranged to represent non-linear functions.

By mounting the conductive strips 118 upon a cylindrical surface instead of on a plane surface a more compact mechanism is achieved. If desired, a stop may be provided to limit rotation of cylinder 101 to one revolution, in which case its operation would correspond to operations involving movement of a contactor card over conductive strips carried by a flat surface as in Fig. 1, or the stop may be omitted in which case the cylinder progresses from maximum to minimum values of the quantity y as rotation beyond the end of the conductive strips 118 occurs. Preferably, the two ends of any one spiral do not overlap so that contactor card cannot engage extremes of a conductive strip simultaneously, for the reason that the portion of scale 113 corresponding to overlapping portions of a conductive strip would have no meaning and would give rise to errors in setting cylinder 101 in accordance with one of the variables. Due to the variable spacing of the successive spirals it will be apparent that if conductive winding 131 on card 129 is of sufficient length to barely engage three conductive strips where values of x are high, it will contact three or more conductive strips where values of x are low. As previously pointed out this gives rise to no disadvantage since the voltmeter 136 registers a reading which is proportional to the position of the center-tap of winding 131 relative to the two conductive strips 118 between which the center-tap is disposed, regardless of whether the conductive winding 131 engages two, three or more of the conductive strips.

The operation of the apparatus shown in Fig. 3 is the same as the operation of the previously described embodiments of the invention. Crank wheel 111 is operated until scale 113 cooperating with indicator pointer 114 registers the value of the variable y that is to be set into the apparatus and crank wheel 127 is rotated until scale 138 cooperating with indicator pointer 137 registers the value of the variable x that is to be set into the apparatus. When this has been done the voltmeter 136 will indicate the voltage of the tap terminal, which is proportional to the posi-

tion of the center tap of card 131 relative to the minimum value of the quantity x and will thereby interpolate between two of the conductive strips 118. The distances represented by the scales 113 and 138 may be expressed in any desired unit.

A further embodiment of the invention is shown in Fig. 5. The reference numeral 151 designates a mounting plate for conductive strips which is in the form of a disc and is mounted for rotation on a shaft 152. Mounting plate 151 has secured thereto an external ring gear 153 with which an idler worm wheel pinion 154 supported by stub shaft 156 meshes. Meshing with pinion 154 is a worm gear 157 secured to shaft 158 journaled in bearing blocks 159. Shaft 158 has a crank 161 secured thereto, by the operation of which mounting plate 151 may be rotated through the cooperation of idler pinion 154 with worm gear 157 and ring gear 153.

A lead screw 162 journaled in bearing blocks 163 extends across mounting plate 151 with its axis parallel to the surface of plate 151 and in spaced relation thereto. Lead screw 162 threadedly supports a frame 164 which is guided by square rod 165 fixedly supported in insulating bushings 167 carried by bearing blocks 163. Frame 164 supports a contactor card 168 having a conductive winding 169 to engage contact strips 171 carried on the surface of mounting plate 151. Winding 169 has a center tap which is electrically connected to a brush 172 which has sliding electrical contact with square rod 163. Lead screw 162 is provided with a crank 173 by means of which rotation may be imparted to the lead screw for moving contactor card 168 radially of disc 151 and the lead screw is also provided with a stop 174 to limit the movement of contactor card 168 so that it cannot be moved beyond the center of mounting plate 151. Frame 164 has secured thereto an indicator pointer 176 which cooperates with a linear scale 177 for indicating the radial position of the center tap of conductive winding 169 with respect to mounting plate 151. One face of ring gear 153 is provided with an indexing scale calibrated in degrees of angle and an indicator pointer 179 mounted on any suitable stationary support, such as one of the bearing blocks 163, cooperates with scale 178.

The conductive rod 166 to which the center tap of winding 169 is connected through brush 172 is connected to one terminal of a voltmeter 181 the other terminal of which is connected to the low potential terminal of a battery 182. A series of resistors 183 is connected across battery 182 and these resistors are connected to the conductive strips 171 in the same manner as in the previously described embodiment of the invention. In Fig. 5 the connections of the conductive strips to the resistors have merely been indicated schematically and no mechanical arrangement of collector rings and brushes has been shown. It will be understood that an arrangement of collector rings and brushes generally in accordance with the teachings of Fig. 3 but appropriate to the arrangement of conductive strips shown in Fig. 5 may be employed.

The system shown in Fig. 5 is arranged to solve a problem involving polar coordinates. Whereas in the polar coordinate system shown in Fig. 2 that portion only of the function which is plotted in the first quadrant of a polar coordinate field is of interest, the system shown in Fig. 5 provides for the solution of a problem involving a function which is plotted in two, three or all four quadrants of the polar coordinate field. The

general equation of the function may be expressed in the relationship $k=f(r,\theta)$. The curves of this function have been shown as spirals having decreasing radius in a counter-clockwise direction around mounting plate 151. As in the case of the rectangular coordinate system shown in Fig. 3 it is necessary to limit these spirals to less than one turn. Each of the spiral conductive strips represents a constant value of the variable quantities r and θ in which the quantity r represents the length of the radius vector and the quantity θ represents the angle between the radius vector and the prime direction. The curves of the particular function shown in Fig. 5 are much closer together at their outer ends than at their inner ends. For this reason it is preferable not to carry all of them into the area where they would crowd closely together but rather to terminate alternate ones short of this area. It is only necessary that the winding 169 on contactor card 168 shall be of sufficient length that it never fails to engage a minimum of two contact strips 171 in any portion of the polar coordinate field. The termination of some of the strips short of the limit of others does not in any way affect the operation of the apparatus. Assuming that the progression of the values of k for the several conductive strips is constant the resistors 183 will be of equal value. When the apparatus is interpolating a position between a long spiral and a short one it is dividing the voltage across one of the resistors 83. When the contactor card moves clear of the outer end of one of the short conductive strips and contacts the two long spirals, one on either side of the short spiral the number of turns of winding 169 between the two long spirals is substantially doubled and the voltage applied to that portion of the winding is doubled because the portion of the winding is now connected directly across two of the resistors 183 so that the card will now interpolate by dividing the voltage across the two long contact strips in accordance with the position of the center tap relative to the two strips in the same manner that it previously interpolated the position of the center tap relative to the long and short conductive strips which the winding engaged.

The apparatus shown in Fig. 5 is operated in the same manner as those previously described. Crank 161 is operated to effect rotation of mounting plate 151 until pointer 179 indicates on scale 178 the desired angle between the radius vector which is the plane of contactor card 168 and the prime direction which is the zero indexing graduation on scale 178. Crank 173 is adjusted until pointer 176 indicates on scale 177 the desired length of radius vector. The exact position of the center tap of winding 169 with respect to the two conductive strips 171 between which it is disposed is then read on voltmeter 181. Since the contact strips 171 are in the form of spirals, contact card 168 cannot intersect the contact strips perpendicularly at all points and may not intersect any of them perpendicularly at any point, depending upon the portion of the function of each spiral that is represented by the contact strips. However, the deviation from perpendicularity will be relatively small and will be of no consequence because the center-tap of winding 169 will divide the space between any two conductive strips substantially proportionally regardless of the slowly changing angle of intersection of the card 168 for changing values of r and θ to produce constant values of k . Furthermore, due to the variation in spacing of the con-

tact strips, winding 169 will necessarily contact more than two conductive strips at certain positions of mounting plate 151. As previously stated this does not affect substantially accurate interpolation between the contact strips immediately adjacent to the center-tap on either side thereof.

With reference to all of the embodiments of the invention generally, it may be stated that the equipotential conductive strips should be sufficiently close together electrically that a linear interpolation of reasonable accuracy is obtained. In some cases a compromise interpolation other than linear may be advantageous particularly if the requirements for accuracy are not uniform over the whole field. The resistance of the winding on the card is preferably high in comparison with the resistances which it bridges so that the effective resistance of the fixed resistor and the portion of the winding on the contactor card in parallel with it will only be slightly less than that of the fixed resistance.

Fig. 6 shows a modified form of contactor card which may be employed instead of a card having a winding of fine wire upon it. This card consists of an assembly of thin laminations alternately of insulating material 181 and conductive material 182. Successive conductive laminations 182 are interconnected by fixed resistors 183 of high resistance value and a center-tap connection 184 is provided at the center of the series of resistors 183. High value resistors of very small size may be employed as the resistors 183 and these may be mounted directly on the contactor card structure.

Whether the contactor card has a continuous winding of wire or consists of laminations it is within the contemplation of the invention to provide a conductive card in which the spacing of successive conductive sections either of turns of wire or of laminations is of the order of .005 inch. This would provide one hundred discrete steps of interpolation between conductive strips spaced one-half inch apart. With this spacing of conductive elements of the contactor card a high degree of accuracy could be attained.

With regard to mechanical problems involved in making and reproducing curved metal conductive strips, a template may be constructed for any set of curves, having uniformly spaced holes along the line of each curve. The template may be placed over a mounting plate which is to be prepared to receive conductive strips, and holes corresponding to those in the template may be drilled through the mounting plate. The conductive strips that are to be mounted on the mounting plate may have uniformly spaced prongs extending downwardly, and upon completion of the drilling of the mounting plate the conductive strips are fitted to the plate by insertion of the prongs into the drilled holes, the conductive strip bending into conformity with the proper curvature as the prongs are fitted into the drilled holes. In the case of the arrangement shown in Fig. 2 in which the conductive strips are straight, no bending would be involved. One type of prong integral with a mounting strip is indicated by the reference numeral 90 in Fig. 2. In the case of Fig. 3 the template for drilling the mounting holes for the conductive strips, instead of being in the form of a flat plate would be a cylindrical sleeve.

It is contemplated that the invention, in any of its several forms, may have utility in the art of directors and computers for supplying gun control data. Such devices perform the solution of

geometrical problems of the type that the present invention is adapted to solve. Since the relative positions of the conductive strips and the contactor may be varied continuously according to each of two variables, these variables may represent the observed movement of a target object at which a gun is to be aimed.

Although certain specific embodiments of the invention have been shown in the drawings and described in the foregoing specification, it will be understood that the invention is not limited to these specific embodiments but is capable of rearrangement and modification without departing from the spirit of the invention and within the scope of the appended claims.

What is claimed is:

1. In a potential divider, a sequence of spaced conductive strips, means for applying to said strips electrical potentials proportional to the sequential relation of said strips, a contactor adapted to engage a minimum of any two adjacent ones of said strips and to interpose a resistive instrumentality having a potential dividing tap terminal between the points of contact with said strips, means for producing relative movement between said conductive strips and said contactor along and transversely of said strips, and means for indicating the electrical potential of said tap terminal.

2. In a potential divider, a sequence of spaced conductive strips presenting narrow contact surfaces, means for applying to said strips electrical potentials proportional to the sequential relation of said strips, a contactor adapted to engage a minimum of any two adjacent ones of said strips and to interpose a resistive instrumentality having a potential dividing tap terminal between the points of contact with said strips, means for producing relative movement between said conductive strips and said contactor along and transversely of said strips, and means for indicating the electrical potential of said tap terminal.

3. In a potential divider, a sequence of spaced conductive strips, means for applying to said strips electrical potentials proportional to the sequential relation of said strips, a contactor winding of relatively fine closely wound insulated wire having the insulation removed from a corresponding portion of each turn of said winding, means for supporting said winding so as to present the exposed portion of the turns of said wire for electrical contact with said strips, said winding being of sufficient length to engage minimum of any two adjacent ones of said strips, means for producing relative movement between said conductive strips and said supporting means along and transversely of said strips, a potential dividing tap terminal for said winding, and means for indicating the electrical potential of said tap terminal.

4. In a potential divider, a sequence of spaced conductive strips having narrow contact surfaces, means for applying to said strips electrical potentials proportional to the sequential relation of said strips, a contactor for said strips comprising a thin flat card of insulating material having a closely wound winding of fine insulated conductive wire, each turn of said winding having the insulation removed at one edge of the supporting card for establishing electrical contact with said conductive strips, means for supporting said wound card edgewise to present the exposed portions of said conductive wire for electrical contact with said conductive strips, means for producing relative movement between said conductive strips and said wound card along said conductive strips

and transversely thereof, a potential dividing tap connection for said contactor winding, and means for indicating the electrical potential of said tap connection.

5. In a potential divider, a sequence of spaced conductive strips, means for applying to said strips electrical potentials proportional to the sequential relation of said strips, a contactor adapted to engage a minimum of any two of said strips and to interpose a resistive instrumentality having a potential dividing tap terminal between the points of contact with said strips, means for producing relative movement between said conductive strips and said contactor along and transversely of said strips, means for maintaining approximate perpendicularity of intersection between said contactor and said strips throughout the field of said relative movement, and means for indicating the electrical potential of said tap terminal.

6. In a potential divider, a platform, a sequence of spaced conductive strips mounted on said platform, means for applying to said strips electrical potentials proportional to the sequential relation of said strips, a carriage movably supported by said platform above said conductive strips, means for moving said carriage to and fro along said platform, a traverse member movably supported by said carriage, means for moving said traverse member to and fro along said carriage, a contactor member supported by said traverse member having a resistive instrumentality adapted to bridge a minimum of two adjacent ones of said conductive strips, said resistive instrumentality having a potential dividing tap terminal, and means for indicating the electrical potential of said tap terminal.

7. In a potential divider, a platform, a sequence of spaced conductive strips mounted on said platform, means for applying to said strips electrical potentials proportional to the sequential relation of said strips, a contactor comprising a resistive instrumentality adapted to bridge a minimum of two adjacent ones of said conductive strips, means for supporting said contactor, means for moving said supporting means relative to said platform in a direction parallel to one edge of said platform, means for moving said supporting means in a direction at right angles to the first-mentioned direction, a potential dividing tap terminal for said resistive instrumentality, and means for indicating the electrical potential of said tap terminal.

8. In a potential divider, a platform, a sequence of spaced curved conductive strips mounted on said platform, means for applying to said strips electrical potentials proportional to the sequential relation of said strips, a carriage movably supported by said platform above said conductive strips, means for moving said carriage to and fro along said platform, a traverse member movably supported by said carriage, means for moving said traverse member to and fro along said carriage, a contactor supported by said traverse member having a resistive instrumentality adapted to bridge a minimum of any two adjacent ones of said conductive strips, means for causing said contactor to intersect any conductive strip which it engages in approximate perpendicularity, a potential dividing tap terminal for said resistive instrumentality and means for indicating the electrical potential of said tap terminal.

9. In a potential divider, a platform, a sequence of spaced curved conductive strips mounted on said platform, means for applying to said strips electrical potentials proportional to the sequential

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relation of said strips, a carriage movably supported by said platform above said conductive strips, means for moving said carriage to and fro along said platform, a traverse member movably supported by said carriage, means for moving said traverse member to and fro along said carriage, a contactor member supported by said traverse member having a resistive instrumentality adapted to bridge a minimum of any two adjacent ones of said conductive strips, pivotally mounted means supported by said platform at a point representing the optimum approximation of equidistance from all portions of each of said curved conductive strips, a rod rigidly secured to said contactor member and slidably mounted in said pivotally mounted member for causing said member to intersect said strips in approximate perpendicularity, a potential dividing tap terminal for said resistive instrumentality and means for indicating the electrical potential of said tap terminal.

10. In a potential divider, a platform, a sequence of spaced conductive strips mounted on said platform, means for applying to said strips electrical potentials proportional to the sequential relation of said strips, means for supporting said platform for pivotal movement about an axis at one corner of said platform, means for imparting pivotal movement to said platform, a contactor adapted to engage a minimum of any two adjacent ones of said strips and to interpose a resistive instrumentality between the points of contact of said strip, means for supporting said contactor, means for moving said supporting means in a straight line, a potential dividing tap terminal for said resistive instrumentality, and means for indicating the electrical potential of said potential dividing tap terminal.

11. In a potential divider, a platform, a sequence of spaced parallel conductive strips mounted on said platform, means for applying to said strips electrical potentials proportional to the sequential relation of said strips, means for supporting said platform for pivotal movement about an axis at one corner of said platform, means for imparting pivotal movement to said platform, a contactor adapted to engage a minimum of any two adjacent ones of said strips and to interpose a resistive instrumentality between the points of contact with said strips, means for supporting said contactor, means for moving said supporting means in a straight line, means for maintaining said contactor perpendicular to said conductive strips for all positions of the supporting means for said contactor and for all pivotal positions of said platform, a potential dividing tap terminal for said resistive instrumentality, and means for indicating the electrical potential of said potential dividing tap terminal.

12. In a potential divider, a platform, a sequence of spaced parallel conductive strips mounted on said platform, means for applying to said strips electrical potentials proportional to the sequential relation of said strips, means for supporting said platform for pivotal movement about an axis at one corner of said platform, means for imparting pivotal movement to said platform, a contactor adapted to engage a minimum of any two adjacent ones of said strips and to interpose a resistive instrumentality between the points of contact with said strips, means for pivotally supporting said contactor, means for moving said supporting means in a straight line, a pair of equal length links pivotally mounted on said platform on a line parallel to said conductive

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strips, a pair of equal length links pivotally engaging said contactor, means having two pairs of pivots on center lines at right-angles to each other connected to said pairs of links to maintain said contactor perpendicular to said strips throughout the straight line movement of said mounting means for said contactor and the pivotal movement of said platform, a potential dividing tap terminal for said resistive instrumentality and means for indicating the electrical potential of said potential dividing tap terminal.

13. In a potential divider, a rotatable cylinder, means for rotating said cylinder, a sequence of spaced conductive strips extending around the periphery of said cylinder, means for applying to said strips electrical potentials proportional to the sequential relation of said strips, a contactor adapted to engage a minimum of any two adjacent ones of said strips and to interpose a resistive instrumentality between the points of contact with said strips, means for supporting said contactor in a plane parallel to the axis of said cylinder, means for moving said mounting means to and fro in a direction parallel to the axis of said cylinder, a potential dividing tap terminal for said resistive instrumentality, and means for indicating the electrical potential of said potential dividing tap terminal.

14. In a potential divider, a rotatable cylinder, means for rotating said cylinder, a sequence of conductive strips carried by said cylinder on the periphery thereof and conformed to the contour of spirals each having a greater pitch than the conductive strips preceding it, means including sliding contact elements for applying to said strips electrical potentials proportional to the sequential relation of said strips, a contactor adapted to engage a minimum of any two adjacent ones of said strips and to interpose a resistive instrumentality between the points of contact with said strips, means for supporting said contactor in a plane parallel to the axis of said cylinder, means for moving said supporting means to and fro along said cylinder parallel to the axis thereof, a potential dividing tap terminal for said resistive instrumentality, and means for indicating the electrical potential of said tap terminal.

15. In a mathematical calculating device, a plurality of spaced conductive strips conformed to geometrical curves representing a series of constant values of a function of two variables, means for applying to said strips electrical potentials proportional to said constant values of the functions, a contactor adapted to engage a minimum of any two adjacent ones of said strips and to interpose a resistive instrumentality between the points of contact with said strips, means for producing compound relative movement between said contactor and said strips according to said two variables, a potential dividing tap terminal for said resistive instrumentality, and means for indicating the electrical potential of said tap terminal whereby to interpolate values of said function intermediate those represented by said conductive strips.

16. In a mathematical calculating device, a plurality of spaced conductive strips conformed to geometrical curves representing a series of constant values of a function of two variables, means for supporting said strips, means for applying to said strips electrical potentials proportional to said constant values of the function, a contactor adapted to engage a minimum of any two adjacent ones of said strips and to interpose a resistive instrumentality between the points of

contact with said strips, means for producing compound movement of said contactor with respect to said strips according to said two variables, a potential dividing tap terminal for said resistive instrumentality, and means for indicating the electrical potential of said tap terminal whereby to interpolate values of said function intermediate those represented by said conductive strips.

17. In a mathematical calculating device, a plurality of spaced conductive strips conformed to geometrical curves representing a series of constant values of a function of two variables, mounting means for said conductive strips, means for applying to said strips electrical potentials proportional to said constant values of the function, a contactor adapted to engage a minimum of any two adjacent ones of said strips and to interpose a resistive instrumentality between the points of contact with said strips, means for moving said strip mounting means with respect to said contactor in accordance with one of said variables, means for moving said contactor with respect to said strips in accordance with the other of said variables, a potential dividing tap terminal for said resistive instrumentality, and means for indicating the electrical potential of said tap terminal whereby to interpolate values of said function intermediate those represented by said conductive strips.

18. In a mathematical calculating device, a plurality of spaced conductive strips conformed to geometrical curves representing a series of constant values of a function of two variables, means for applying to said strips electrical potentials proportional to said constant values of the functions, a contactor adapted to engage a minimum of any two adjacent ones of said strips and to interpose a resistive instrumentality between the points of contact with said strips, means for producing compound relative movement between said contactor and said strips according to said two variables, individual scale and pointer means for indicating each of said variables, a potential dividing tap terminal for said resistive instrumentality, and means for indicating the electrical potential of said tap terminal whereby to interpolate values of said function intermediate those represented by said conductive strips.

19. In a potential divider, a sequence of spaced conductive strips, means rotatable about an axis for supporting said strips, means including sliding electrical contact members for applying to said strips electrical potentials proportional to the sequential relation of said strips, a contactor adapted to engage a minimum of any two adjacent ones of said strips and to interpose a resistive instrumentality between the points of contact with said strips, means for rotating said contact strip supporting means relative to said contactor, a potential dividing tap terminal for said resistive instrumentality, and means for indicating the electrical potential of said tap terminal.

20. In a mathematical calculating device, a plurality of spaced conductive strips conformed to sections of geometrical curves representing a series of constant values of a function of two variables for a predetermined range of values of each of said variables, a plurality of additional conductive strips conformed to shorter sections of geometrical curves representing other constant values of the same function within lesser ranges of values of said variables as the field of geometrical curves affords spacial accommodations for said shorter sections, means for applying to said

strips electrical potentials proportional to said constant values of the function, a contactor adapted to engage a minimum of any two adjacent ones of said strips and to interpose a resistive instrumentality between the points of contact of said strips, means for producing compound relative movement between said contactor and said strips according to said two variables, a potential dividing tap terminal for said resistive instrumentality, and means for indicating the electrical potential of said tap terminal whereby to interpolate values of said function intermediate those represented by said conductive strips.

21. In a potential divider, a sequence of spaced conductive strips, means for applying to said strips electrical potentials proportional to the sequential relation of said strips, a contactor adapted to engage a minimum of any two adjacent ones of said strips and comprising a series of alternate thin laminations of conductive and non-conductive material and a fixed resistor bridging each two adjacent ones of said conductive laminations, means for producing relative movement between said conductive strips and said contactor, a potential dividing tap terminal for the interconnected series of resistors of said contactor, and means for indicating the electrical potential of said tap terminal.

22. In a potential divider, a sequence of spaced conductive strips, means for applying to said strips electrical potentials proportional to the sequential relation of said strips, a contactor adapted to engage a minimum of any two adjacent ones of said strips and comprising a plurality of thin laminations of conductive material insulated from each other and having a fixed resistor interconnecting each two adjacent ones of said conductive laminations, said fixed resistors being of equal value, means for producing relative movement between said conductive strips and said contactor, a potential dividing tap terminal for said series of interconnected resistors of said contactor, and means for indicating the electrical potential of said tap terminal.

23. In a potential divider, a rotatable member, means for rotating said member, a sequence of conductive strips carried by said member on a principal surface thereof and conformed to spirals having an extent of less than one revolution of said member, means for applying to said strips electrical potentials proportional to the sequential relation of said strips, a contactor adapted to engage a minimum of any two adjacent ones of said strips and to interpose a resistive instrumentality between the points of contact with said strips, means for supporting said contactor in transverse relation to said strips at the point of engagement with said strips, means for moving said mounting means to and fro in a direction parallel to the plane of said contactor, a potential dividing tap terminal for said resistive instrumentality, and means for indicating the electrical potential of said potential dividing tap terminal.

24. In a potential divider, a sequence of spaced conductive strips, means for applying to said strips electrical potentials proportional to the sequential relation between said strips, a contactor adapted to engage a minimum of any two adjacent ones of said strips comprising a plurality of alternate thin laminations of conductive and insulating material and a fixed resistor connected between each two adjacent ones of said conductive laminations, means for supporting said contactor for engagement of said conductive lami-

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nations with said strips, means for producing relative movement between said conductive strips and said supporting means along and transversely of said strips, a potential dividing tap terminal at substantially the mid-point of said resistors, and means for indicating the electrical potential of said tap terminal.

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REFERENCES CITED

The following references are of record in the file of this patent:

22**UNITED STATES PATENTS**

Number	Name	Date
1,345,706 ✓	Routin -----	July 6, 1920
1,707,274 ✓	Morse -----	Apr. 2, 1929
1,971,238 ✓	Silling -----	Aug. 21, 1934
2,114,330 ✓	Borden -----	Apr. 19, 1938
2,220,951 ✓	Borden -----	Nov. 12, 1940